A VERSATILE TESTER FOR LINEAR INTEGRATED CIRCUITS*

by James N. Giles

I. INTRODUCTION

One problem that arises when using an integrated circuit is that if it doesn't operate properly in a particular circuit, the engineer is often at a loss to determine whether the device is defective or the circuit design is at fault. About the only recourse available is to try several devices in the circuit and see if any better results are obtained. What is needed to solve this problem is a simple tester, similar to the curve tracer used with transistors, to determine if a unit is working properly. Such an instrument is described here.

This tester is specifically designed to check the following Fairchild standard linear integrated circuits: the μA 702A wideband DC amplifier,[1,2,3,4] the μA 709 high-performance operational amplifier,[5] the μA 710 high-speed differential comparator,[6] and the μA 711 dual comparator.[6,7] The test method is applicable to practically all linear circuits, however; and the tester can be easily modified to handle new devices as they become available.

Except for the display oscilloscope, the tester is completely self-contained; so it is not necessary to dig up power supplies, special test jigs, and other miscellaneous equipment to test a single device. Relatively complete and rapid testing is possible with the unit, making it valuable both in the laboratory and for incoming inspection.

A photograph of the front panel of the tester is shown in Fig. 1. A separate TO-5 socket is used for each device type, with connections to each socket made by a selector switch.

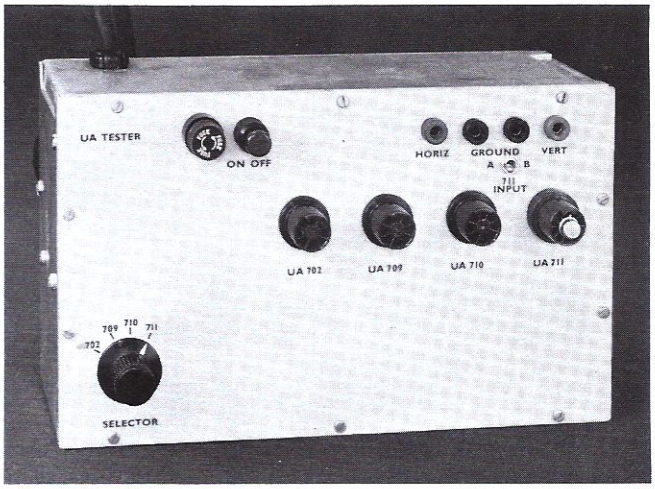


FIG. 1. Front view of the tester

Sockets for flat packs can be easily added if desired. The scope inputs are connected to the HORIZ-VERT banana jacks shown at the upper-right side of the chassis. The circuitry of the tester is fairly simple and straightforward, as can be seen from the bottom view in Fig. 2.

*Reprinted in part from EEE, with permission of the publisher.

COPYRIGHT, FAIRCHILD SEMICONDUCTOR, 1966 • PRINTED IN U.S.A. 2320-252-76 10M

FAIRCHILD SEMICONDUCTOR
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
313 FAIRCHILD DRIVE, MOUNTAIN VIEW, CALIFORNIA, (415) 962-5011, TWX: 910-379-6435

Fairchild cannot assume responsibility for use of any circuitry described other than circuitry entirely embodied in a Fairchild product. No other circuit patent licenses are implied.

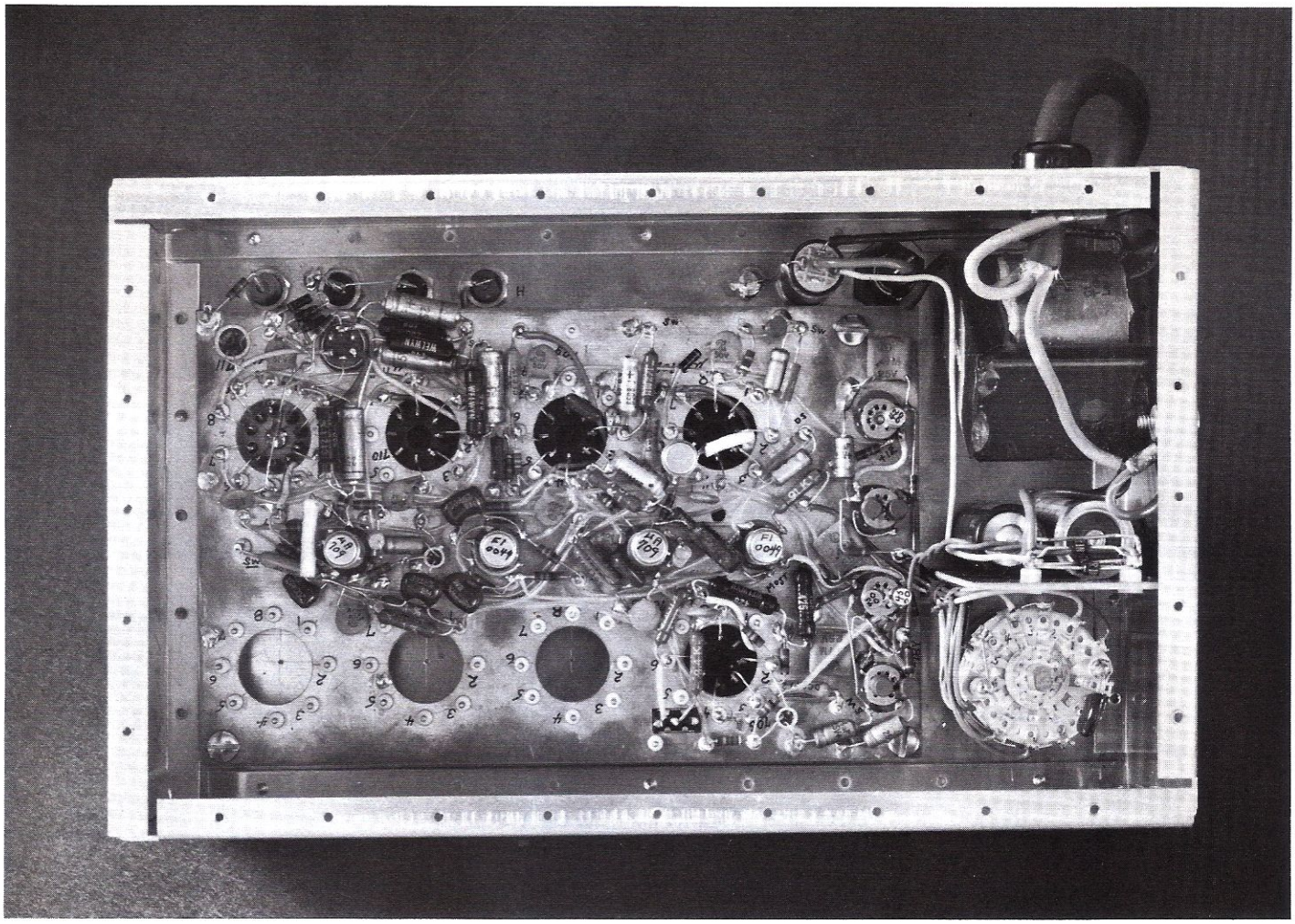


FIG. 2. Rear view of the tester

To test a device, one simply selects the type with the selector switch, plugs the device into its socket, and reads the test parameters from the scope. Gain, linearity, output voltage swing, and input offset voltage are all simultaneously displayed. The scope used with the tester must have an external horizontal sensitivity of 1 V/div and a vertical sensitivity of 0.1 V/div; 10-division vertical and horizontal scales are desirable, but not absolutely necessary. A Fairchild type 702 scope was used for the scope photos shown in the figures.

II. BASIC CIRCUIT

All parameters tested except offset are found from the amplifier open-loop transfer function, which is a display of the input/output characteristics of the circuit over its full dynamic range. The transfer function is obtained by applying the AC input and output signals of the device under test (DUT) to the scope horizontal and vertical inputs, respectively. The resultant scope trace is a plot of amplifier output versus input—maximum output voltage swing, linearity, and gain can be determined from the curve as shown in Fig. 3.

For high-gain DC amplifiers, the offset voltage must be balanced out before the transfer function can be displayed. This is because the gain is very high, and a few millivolts of

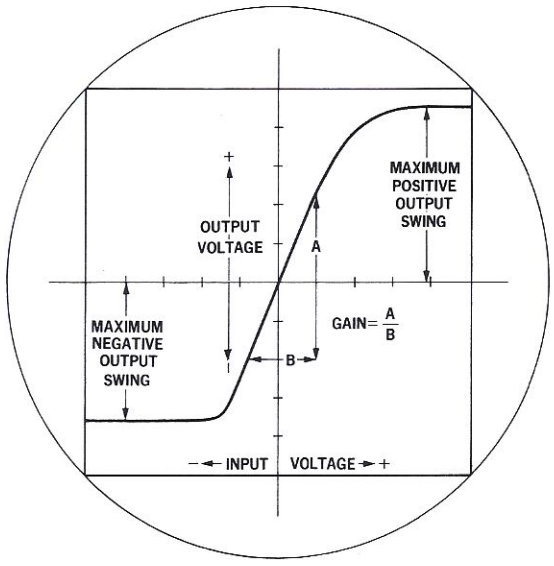


FIG. 3. Transfer function display

offset are enough to hold the output in saturation over most or all of the input cycle. Manual adjustment of the offset is not desirable since it would greatly increase the test time for each unit. An accurate and automatic means of nulling

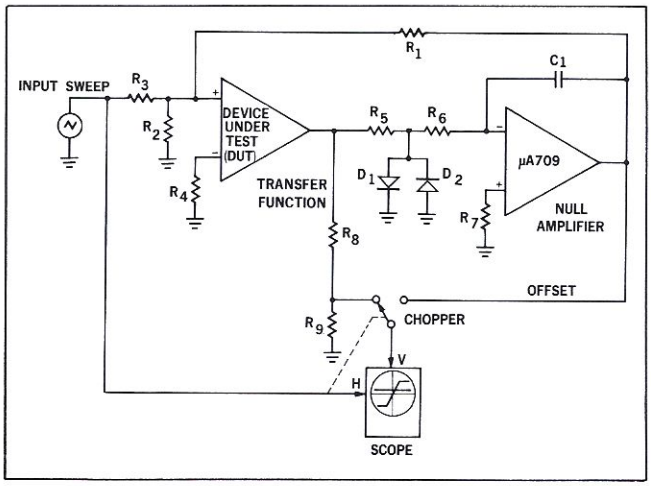


FIG. 4. Basic circuit for displaying transfer function and offset volt.

the offset is shown in Fig. 4. A μA 709 operational amplifier is used in a feedback loop around the DUT. The μA 709 holds the DUT output at zero by adjusting the DC voltage at the DUT input so that it is equal to the offset. Hence, the μA 709 output voltage is simply equal to the offset multiplied by the ratio of the precision feedback resistors, R_1/R_2. This provides a convenient high-level point for accurately measuring the offset and eliminates the need for a high-gain DC vertical amplifier.

The AC signal for the transfer function is applied to the DUT input through a precision attenuator (R_2, R_3). Taking the scope horizontal input from the high-level end of the divider eliminates the need for a high-gain horizontal amplifier. An internal feedback loop (C_1, R_6) around the μA 709 null amplifier removes the feedback at the signal frequency so the DUT is operated open-loop for the transfer function test. Since the null amplifier responds to the average value of the DUT output when it is overdriven for the transfer function display, the offset readout will be accurate only if the AC signal is perfectly symmetrical about ground. Therefore, for devices with unequal positive and negative output voltage swings (such as the μA 710), it is necessary to add a pair of matched diodes (D_1, D_2) to symmetrically clip the signal before it reaches the null amplifier.

The offset voltage and transfer function are simultaneously displayed on the scope by use of a chopper at the vertical input. The chopper switches in synchronism with the horizontal sweep such that the transfer function is displayed for one-half of the sweep cycle and the offset voltage on the return trace. A precision attenuator at the DUT output reduces the transfer function signal to a level compatible with the offset voltage signal so both can be displayed on the same sensitivity vertical scale of the scope. Knowing the scale factors, then, the offset, gain, linearity, and output swing of each device can be read directly off the scope display.

III. DETAILED CIRCUIT

The complete circuit diagram of the tester is given in Fig. 5. A single null amplifier serves for all devices, with connections to the DUT being made by a rotary switch. The highest source resistance specified for each circuit type is used for the offset test; this measures the combined effects of both input offset voltage and input offset current, which is more useful than offset voltage alone. The source resistances are 2 kΩ for the μA 702A, 10 kΩ for the μA 709, and 200 Ω for the μA 710 and μA 711.

The feedback ratio for the offset measurement is 100; hence, using a scope DC vertical scale sensitivity of 0.1 V/div, one division corresponds to one millivolt of input offset voltage. The precision attenuators in the transfer function part of the circuit are chosen to give vertical scale factors of 1 V/div for the μA 702A, μA 710, and μA 711, and 4 V/div for the μA 709. The AC sweep signal is 10 volts peak-to-peak at a frequency of 1 kHz; using the 1 V/div horizontal scale, the input voltage scale factors are 1 mV/div for the μA 702A, μA 710, and μA 711, and 0.2 mV/div for the μA 709. Power supply voltages are +12 V, -6 V for all devices except the μA 709, which is ± 12 V.

Device Socket Connections

The useful symmetrical output dynamic range of the μA 702A is about ± 5 volts, although the output can swing as far as 11 volts in the positive direction. Limiting the positive output swing to 6 volts with the diode network (D_1, D_2) at the lag frequency-compensation terminal helps to keep the signal symmetrical so the offset readout will be accurate. This also permits the ± 5 volt range to be displayed over the full face of the scope without overloading, so the transfer function parameters can be read more accurately.

The very high gain of the μA 709 makes it necessary to include additional frequency compensation to keep the closed-loop feedback system from oscillating. This is provided by the 15 pF capacitor across the frequency-compensation terminals and the RC network (R_{12}, R_{13}, C_{10}) at the output.

The μA 710 and μA 711 comparators use the same test circuitry since both are specified under the same conditions. The transistor-diode network (Q_1, D_3, R_{18}) at the DUT output holds the DC output at the +1.4 V logic threshold voltage

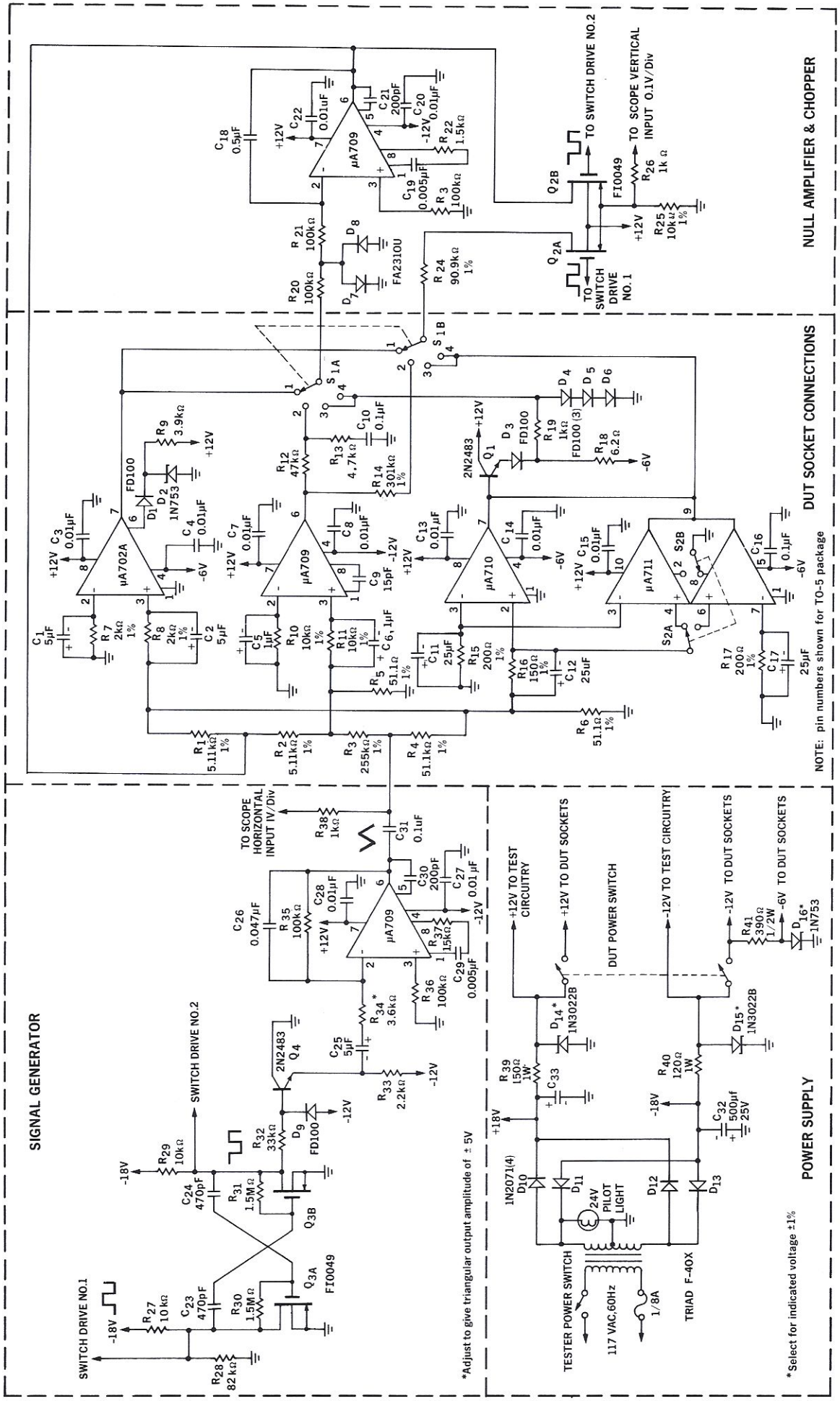
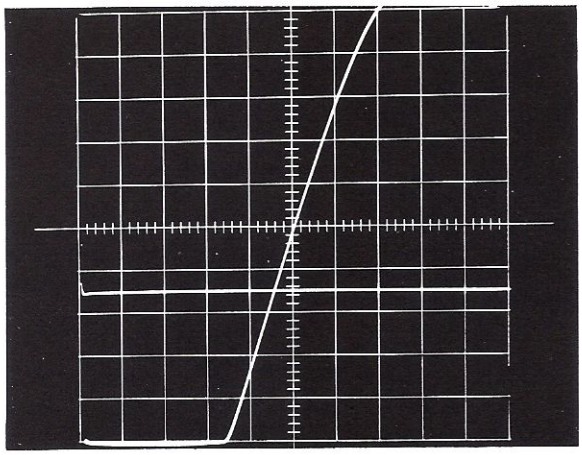
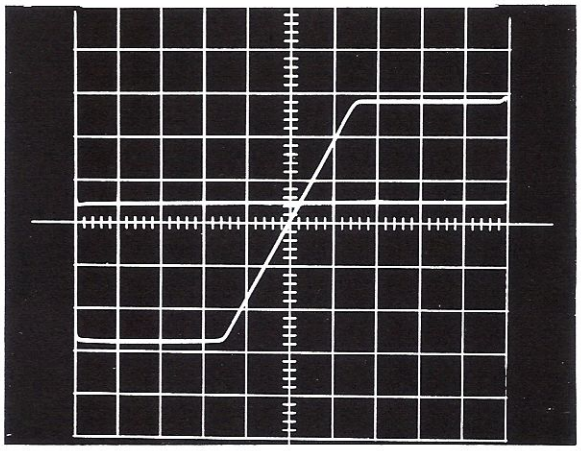


FIG. 5. Complete circuit diagram



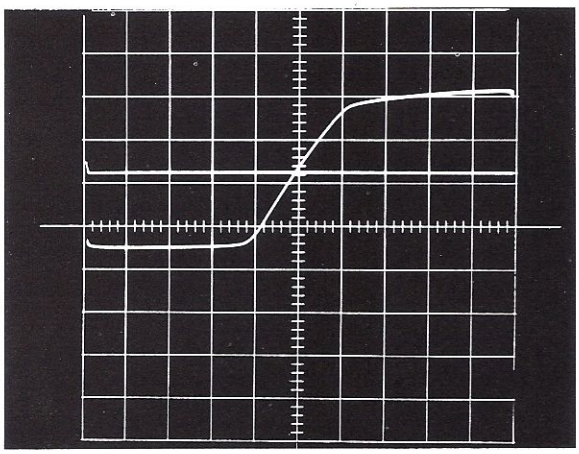
TRANSFER FUNCTION: VERTICAL = IV/div
HORIZONTAL = ImV/div
OFFSET: VERTICAL = ImV/div

FIG. 6. μA702A display



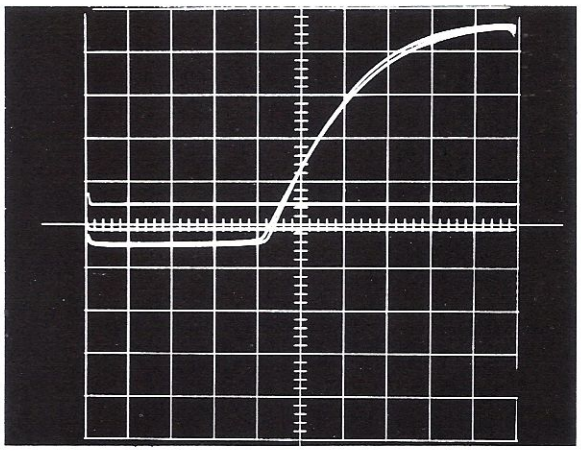
TRANSFER FUNCTION: VERTICAL = 4V/div
HORIZONTAL = 0.2mV/div
OFFSET: VERTICAL = ImV/div

FIG. 7. μA709 display



TRANSFER FUNCTION: VERTICAL = IV/div
HORIZONTAL = ImV/div
OFFSET: VERTICAL = ImV/div

FIG. 8. μA710 display



TRANSFER FUNCTION: VERTICAL = IV/div
HORIZONTAL = ImV/div
OFFSET: VERTICAL = ImV/div

FIG. 9. μA711 display
(double exposure showing display for each side)

where the offset is specified. The additional diode string (D_4, D_5, D_6) clamps the positive voltage swing so the signal going into the null amplifier will be nearly symmetrical. A toggle switch is used for the μA711 to switch the strobe and input terminals so the parameters of either half of the comparator can be displayed.

Null Amplifier and Chopper

Frequency compensation for the μA709 null amplifier is provided by C_{19}, R_{22}, and C_{21}. The feedback capacitor, C_{18}, should be nonpolarized since the voltage across it may be of either polarity. Matched diodes D_7 and D_8 perform the final clipping for the DUT output to ensure symmetry for an accurate offset display.

The chopper is a FI0049 dual MOST which performs this function quite well with a minimum of components. Resistors R_{24} and R_{25} form the precision attenuator for the DUT output signal.

Signal Generator and Power Supply

The chopper drive signals and the transfer function sweep are generated by another dual MOST and μA709. The MOST operates as a 1 kHz astable multivibrator, developing the large voltage swings needed to drive the chopper. One of the drive signals is applied to the μA709 integrator through an emitter-follower buffer. Integration of the square wave produces the ±5 V triangular sweep required for the transfer function display.

The power supply is a straightforward full-wave rectifier with zener-diode regulators to provide the ± 12 V and -6 V supplies for the tests.

IV. TYPICAL DISPLAYS

The scope photos of Figs. 6 through 9 were all taken with actual scope DC sensitivities of 0.1 V/div vertical and 1 V/div horizontal. Scale factors for each display are given next to the figures.

A typical μA 702A display is shown in Fig. 6. The unit has a -1.5 mV offset for 2 kΩ source resistances, a 5.1 V negative output swing, and a gain of 3000.

The μA 709 of Fig. 7 has an offset of +0.5 mV for 10 kΩ source resistances, an output swing of ± 11 V, and a gain of 38,000. The output swing is quite symmetrical, and nonlinearity is too small to measure.

Figure 8 shows a typical μA 710 display. This particular unit has an offset of +1.3 mV, a gain of 1500, a +3.1 V positive output level, and a -0.5 V negative output level. The nonlinearity is unimportant since the device is specified and used as a comparator and not an amplifier.

Figure 9 is a double-exposure showing the characteristics of both sides of a μA 711. The gains are 1800, swings are +4.6 V and -0.5 V, one side has a +0.5 mV offset, and the other a -0.1 mV offset.

V. CONCLUSION

A simple but useful tester has been described that can rapidly make a relatively complete test on a number of different linear integrated circuits. Although designed specifically for the Fairchild μA 702A, μA 709, μA 710, and μA 711, the test method presented can be used to test practically any amplifier circuit. The tester should find its greatest use in testing circuits at incoming inspection and as a curve-tracer-type tester in the engineering laboratory.

VI. REFERENCES

1. R. J. Widlar, "A Monolithic Operational Amplifier," Fairchild Semiconductor APP-105/2.

2. R. J. Widlar, "The Improved μA 702 Wideband DC Amplifier," Fairchild Semiconductor APP-111/2.

3. "μA 702 Circuit Design Ideas," Fairchild Semiconductor APP-114.

4. J. N. Giles, "Frequency Compensation Techniques for an Integrated Operational Amplifier," Fairchild Semiconductor APP-117.

5. R. J. Widlar, "A Unique Circuit Design for a High Performance Operational Amplifier Especially Suited to Monolithic Construction," Fairchild Semiconductor TP-32.

6. R. J. Widlar, "The Operation and Use of a Fast Integrated Circuit Comparator," Fairchild Semiconductor APP-116.

7. R. J. Widlar, "Core Memory Sense Amplifier Designs Using an Integrated Dual Comparator," Fairchild Semiconductor APP-123.

8. R. J. Widlar and J. N. Giles, "Designing with Off-the-Shelf Linear Microcircuits," Fairchild Semiconductor APP-124.